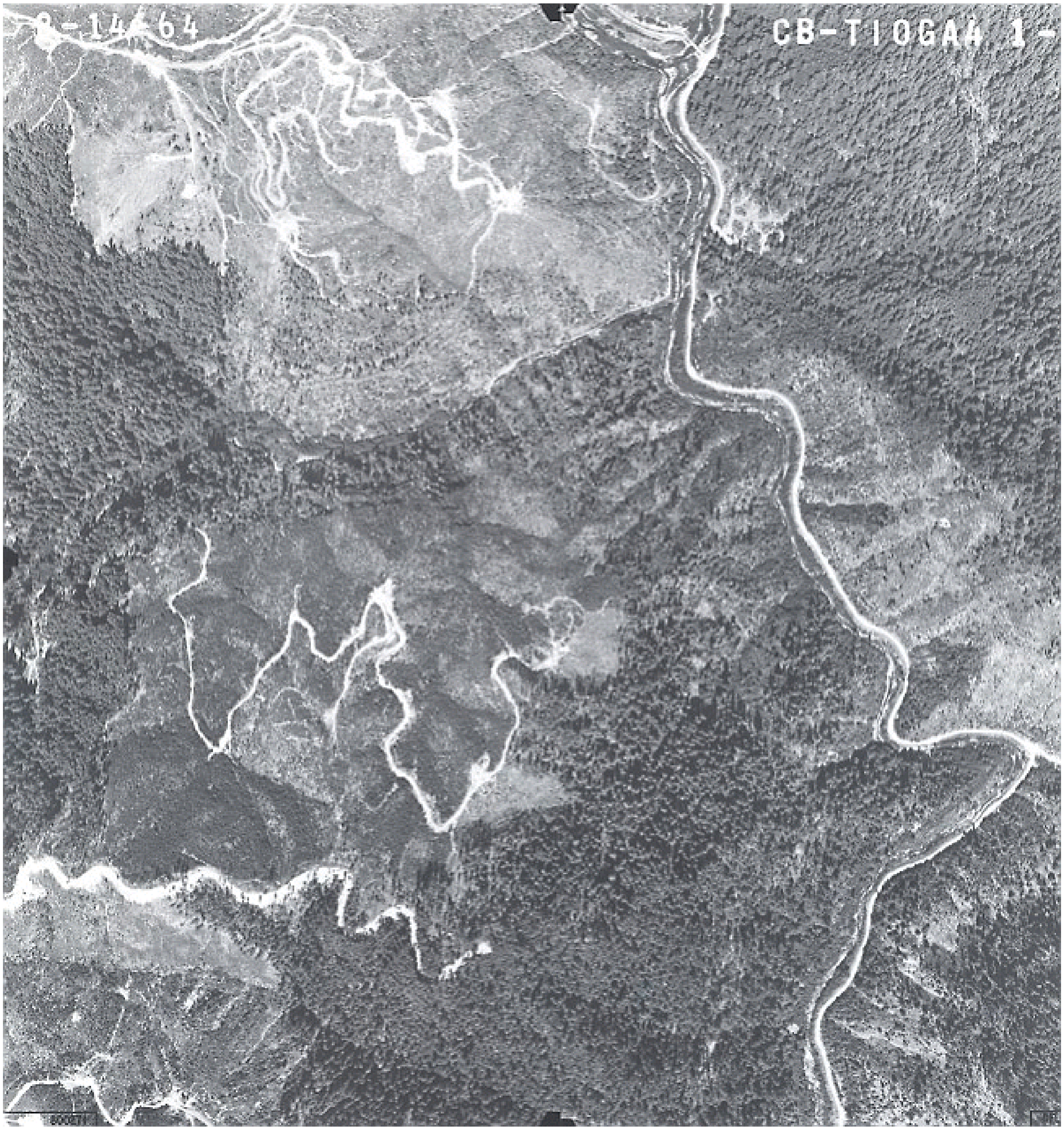

Figure 7: Lower Tioga Creek in 1964. Compare this photo (*I*-10) to the 1965 aerial photograph (5-10)shown in Figure 8.

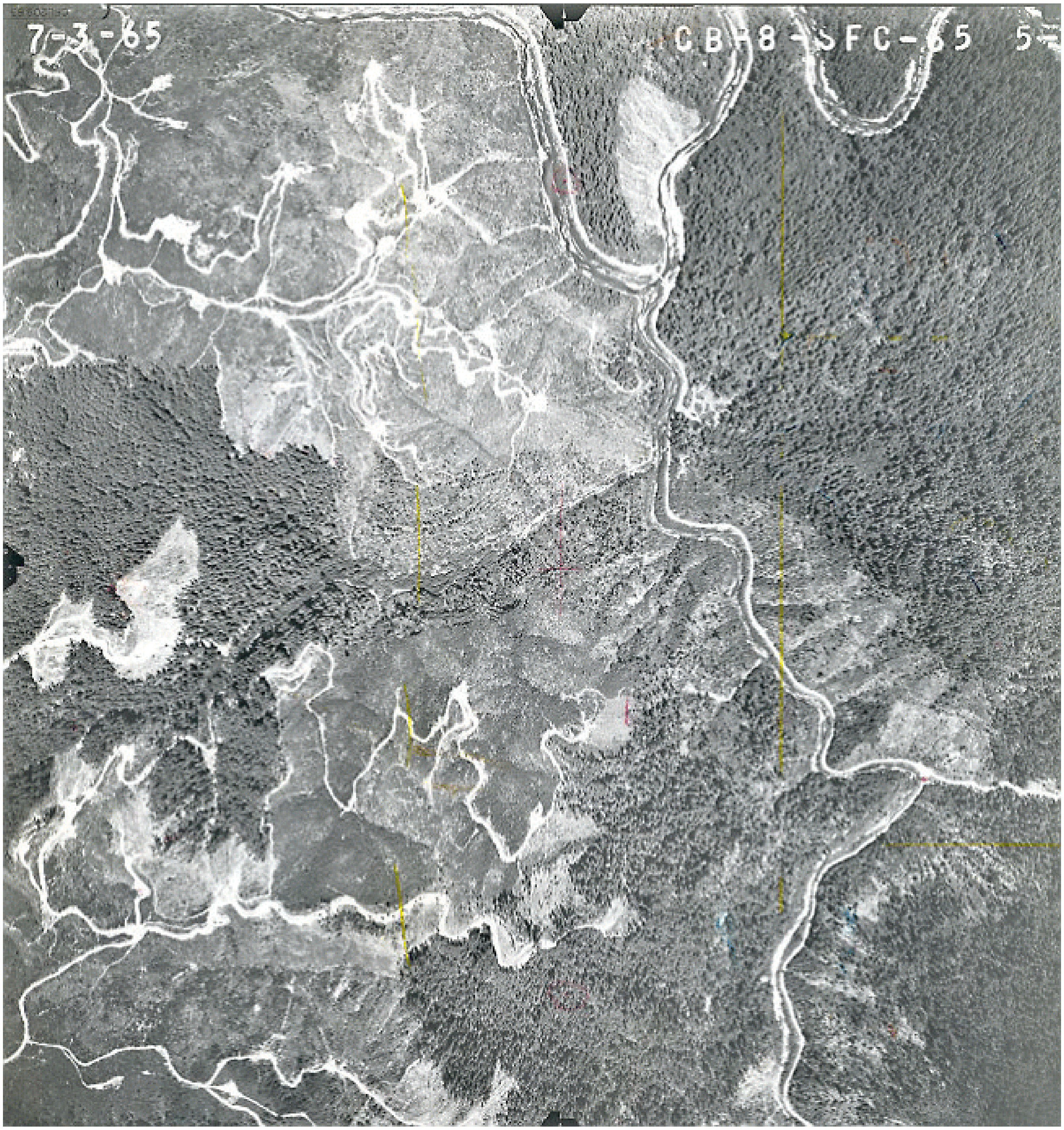

Figure 8: Lower Tioga Creek as shown on the 1965 aerial photograph (Comparison of the 1964 (*1*-10) and 1965 (*5*-10) photographs of lower Tioga Creek.

1965 to 1975

The 1976 photographic set and BLM stream surveys (Boyce, 1970) suggested that this decade was the most active period for hillslope failures and sediment/ woody debris delivery to Tioga Creek and its tributaries. Intensive logging activities during a wet cycle was responsible for this phenomenon.

1970 Physical & Biological Stream Survey

In 1970, the US BLM conducted physical and biological stream surveys which provided a glimpse of the general substrate, fish habitat and riparian vegetation conditions of Tioga Creek at that time. Table 2 is a summary of Ron Boyce's survey. Figure 9(a) is a plot of his estimates of gravel area and pool volumes and Figure 9(b) is a plot of his gradient estimates.

Table 2: US BLM physical and biological stream survey, Boyce (1970).

RIVER MILE	CHANNEL SUBSTRATE	RIPARIAN VEGETATION
0.0-0.30	Mostly bedrock or boulders, very little gravel	20-yr old alder, evergreen, myrtle, 50% shade
0.30-0.60	Mostly boulders	Alder, maple, myrtle, fir; 70%
0.60-0.90	Mostly bedrock pools with large rocks with very little gravel	Alder, 70%
0.90-1.20	Deep, large bedrock pools with large rocks	Alder, 70%
1.20-1.35	Mostly bedrock pools with large rocks Just downstream of Shotgun Creek	Alder, 75%
1.35-1.55	Improved gravel supply	

Descriptions of substrate suggest that the braided bars visible in the aerial photos of 1965 had been flushed out of lower Tioga Creek during the late 1960's.

1.55-1.95	Fairly deep pools with fair amount of fish & gravel.	Alder, 70%
2.0-4.0	Boulder pools with occasional spawning gravels.	
4.00-4.12	Gravels	
4.12-4.25	boulder pools	
4.25-4.50	Silted, bedrock pools and large diameter gravels	
4.6	Excellent spawning areas, a few hundred yards downstream of Hog Ranch Creek	25 year old alders
4.8-5.0	gravels on the sides of a bedrock channel	20 year old alder
5.0-5.5	Bedrock pools, many gravel bars in the upper half.	
5.5-5.75	Hundreds of yards of gravels	
5.75-6.0	Solid bedrock pools with no cover”	
6.0-6.7	Bedrock and silt pools and only one spawning area	
6.7-7.0	Gravels dominated	
7.0-7.5	bedrock, silt and pools	
7.5-8.0	Gravel riffles between bedrock and silt pools	
8.0	Bedrock-silt pools separated by gravel bars	
8.47	Tioga Creek falls	
8.75-9.5	40% good to excellent spawning areas	Excellent streamside cover of alder, maple and myrtle
9.0-9.25		Logged around 1950
9.75-10.0	Marginal gravels	Logged around 1950
	Bedrock falls that were blasted to create a fish ladder in 1962.	
10.5-10.75	Bedrock-silt pools	20-25-year old alder and maple
11.0-11.25	A good supply of gravel and P/R ratio	Good streamside cover
	This is around the mouth of Tributary 14R, the one that witnessed a debris torrent in the early 1970's	
11.25-11.75	A fair gravel supply	20-25 year old riparian vegetation of alder and maple
11.75-12.0	A fair gravel supply	
11.75		Old growth riparian forest
12.0	Substrate and gradient increased	
12.0-12.25	“Basketball” sized substrate, fair gravel supply	Old growth riparian
12.25-12.45	Boulder cascades and boulder-pools	
12.45-12.5	Gravel-dominated. Coho and cutthroat were reportedly abundant.	
12.5-13.0	Gravels	Old-growth riparian of maple, alder, evergreen and myrtle
12.8	A log jam, 6'*30'*12'	
13.0-13.25	Bedrock with sparse gravel	

Table 2, cont: US BLM physical and biological stream survey, 1970.

RIVER MILE	CHANNEL SUBSTRATE	RIPARIAN VEGETATION
13.25-13.5	Gravel in good supply	
13.5-13.75	Mostly large boulders	
13.75-14.25	Boulder cascades with intervening pools that contained many fish, and a beaver dam	
14.06	Logs and debris jam, 8' x 60' x 12', passable	
14.07	Scattered logs and debris	
14.10	Logs and debris passable	
14.12	Large logs- passable...	
14.18	Log jam, 8' x 50' x 20' with a 5 foot fall...	
14.20	Small log and debris jam...	
14.26	8 foot fall over large boulder + log jam, 3-4 foot diameter logs	
14.30	60 steelhead, 30 coho, 15 cutthroat trout / 100 ft.	
14.32	Log jam, 8' x 45' x 8'	
14.37	Log jam, 5' x 30' x 10'	
14.40	Excellent spawning area	
14.25-14.37	Large boulder with pool areas and fast water	
14.37-14.5	Gravels	
14.5	End of survey	

Note in Figure 9(a) that both the area of gravel and pool volume were relatively low in the lower 6 miles of Tioga Creek. Most of the channel substrate was identified as bedrock and boulder-dominated while riparian vegetation was 20-25-year old alder (Table 2). Figure 9(b) shows that the gradient in this reach fluctuated between 0.5 and 2 %. Between mile 6.0 and 9.5, gravel area and pool volumes increased substantially and the gradient is between 1 and 2.5%. This is where the stream valley flows from west to east (Figure 1) and is moderately unconfined.

"Silt pools separated between gravel bars" was the typical descriptor in this reach.

Between mile 9.5 and 12.5, the Tioga Creek channel became more confined, gravel storage was minimal and pool volumes decreased (Figure 9a).

The reach between mi. 9.75-10.0, also logged around 1950, had bedrock falls that were blasted to create a fish ladder in 1962. Gravels were considered "marginal." Bedrock-silt pools dominated mi. 10.5-10.75 with 20-25-year old alder and maple forming the riparian vegetation. It wasn't until mi. 11.0-11.25 that gravel deposits resumed. A "good supply of gravel" and "good pool-riffle ratio and good streamside cover" were noted. (This is around the mouth of Tributary 14R, the one that witnessed a debris torrent in the early 1970's). A "fair gravel supply" and 20-25 year old riparian vegetation of alder and maple were noted between mi. 11.25-11.75. At mi.11.75-12.0, a "fair gravel supply" was noted. Above mi.11.75, old growth riparian vegetation of maple, alder, Douglas fir and myrtle was noted.

Above mile 12.5, boulder cascades and pools were separated by considerable amounts of gravels stored behind numerous log jams.

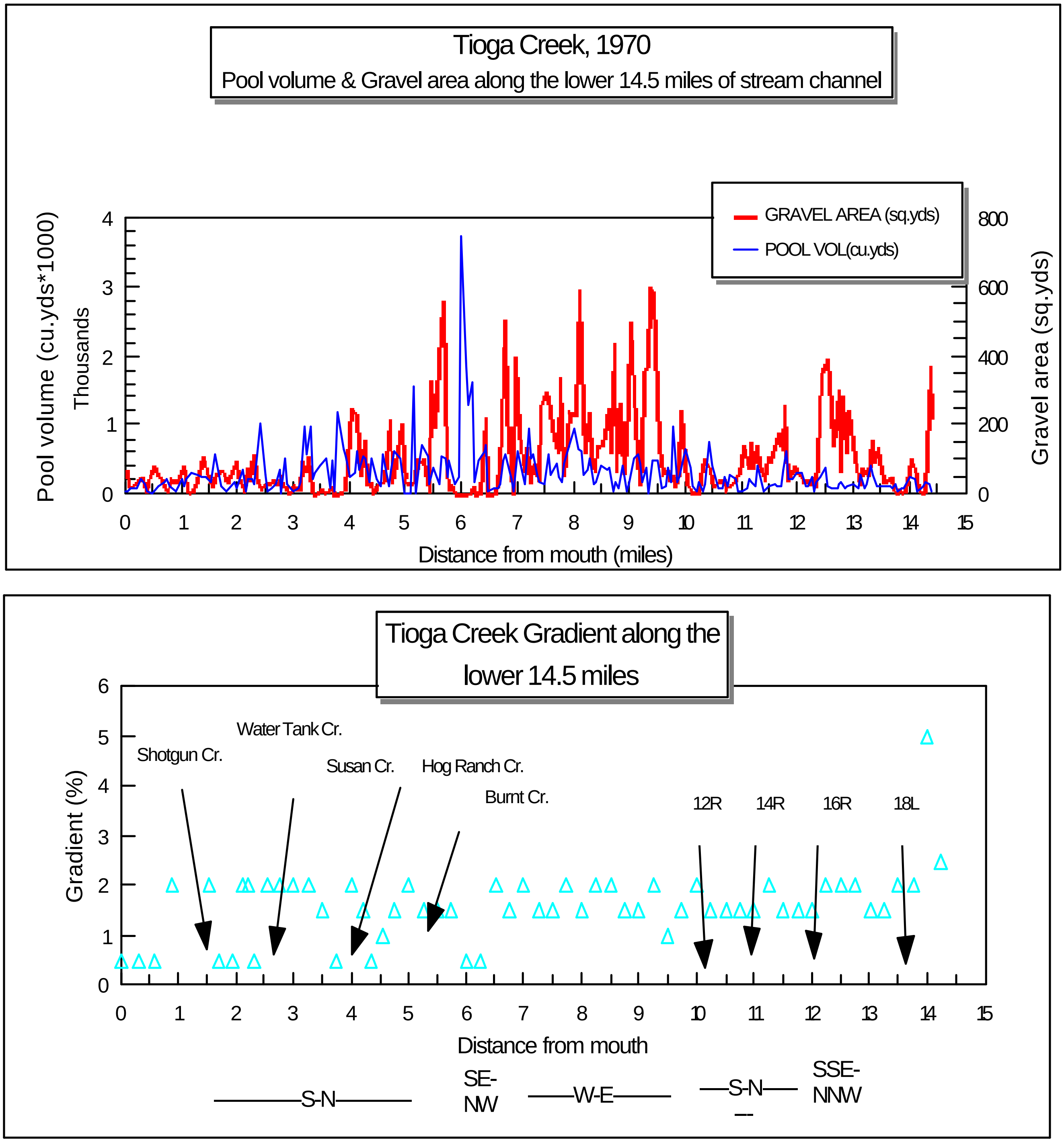

Figure 9: (a.) Plot of gravel area and pool volume estimates by R. Boyce, 1970.
(b.) Plot of the channel gradient in the lower 14.5 miles of Tioga Creek using Boyce's estimates.

1976 Color Infrared

When comparing this color-IR photo set with the 1965 set, the most striking difference in channel morphology, particularly in lower Tioga Creek, was the regeneration of riparian vegetation and the increasing confinement of the channel. This time marks the onset of a **channel degradation phase** in **lower Tioga Creek**. At the mouth of Tioga Creek, the diagonal bars seen in the 1965 photos were gone, having been flushed out, exposing the armor layer of boulder and bedrock. On the banks and some channel bars, a canopy of red alders were forming (Photos *30A*-26through*30A*-28 [Figure 10 is photo *30A-27*]).

The middle reach of **Hatcher Creek** showed a rotational slump that originated at a road cut in a recently harvested area in the S ½ of the NE 1/4 Sec.13, T 26 S, R 10 W that formed a debris slide or torrent that flowed down a SE-flowing draw and into the mainstem Hatcher Creek (*30A*-27[Figure 10] and *30A*-28). It ended near the confluence of the two main forks of Hatcher Creek, a distance of about 1,600 ft. The E-flowing draws in the headwaters of Hatcher Creek in the E ½ of Sec. 23, T 26 S, R 10 W, freshly scoured in 1955, did not appear to have been reactivated at this time.The road that had been punched up the Hatcher Creek valley in the 1960's and the timber harvesting in the late 1960's reduced the stability of the channel and riparian vegetation to withstand this debris torrent. This and possibly other events apparently deposited large volumes of woody debris into Hatcher Creek. Stream surveys by Boyce in 1970 (BLM Tioga Creek

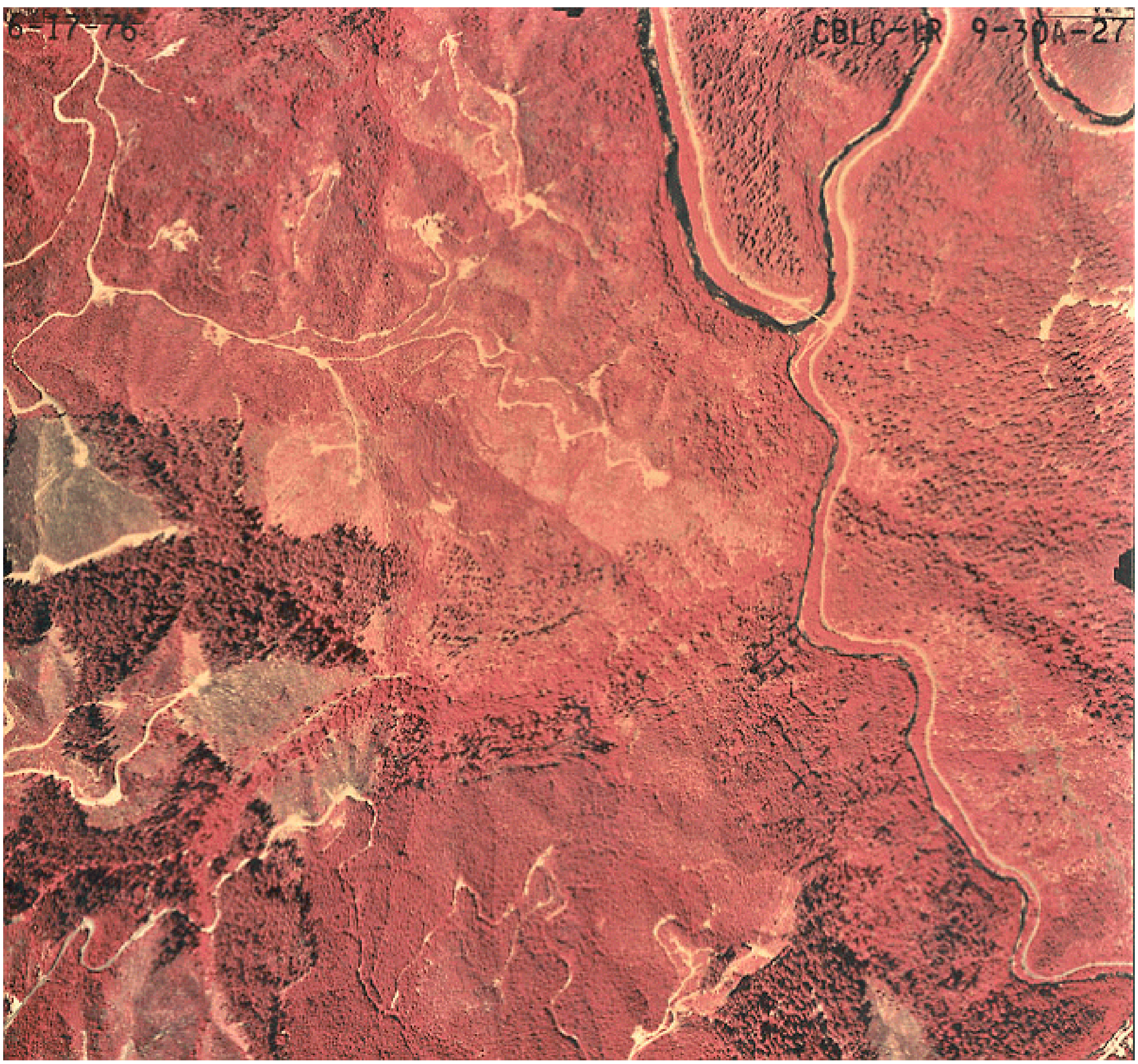

Figure 10: The 1976 photo, *9-30A*-27 showing lower Tioga Creek and Hatcher Creek. When comparing the morphology of Tioga Creek with that observed in the 1965 photo (Figure 8), note the decrease in channel width, lack of diagonal bars and the maturity of riparian vegetation- all indicators of a reduction in sediment supply and a lowering of the channel bed.

Figure 11: The 1976 photo, *8-29*-36 showing Tioga Tributary 14R. Note the rotational slumps originating on the road and the barren nature of the lower valley.

Surveys) identified 17 log and debris jams in the lower 1.25 miles of Hatcher Creek. He described "solid logs" between mi. 0.84-0.87, 0.95-1.0, 1.15-1.18, "large dirt and log piled by slide" at mi. 1.18 and the "lower stream silted due to slides."

Water Tank Creek was mostly in early seral stages. Logging-related slides, visible in 1955 and 1964, had healed by this time *(9-30A*-25-- *9-30A*-26) as indicated by the young alder stands visible at the mouths of the tributaries.

The largest debris torrent evident in all the aerial photographs analyzed was seen in Tioga Tributary **14R** (Figures 11 & 12). Its headwaters of this a NE-flowing tributary draining the NE 1/4 Sec. 14, T 27 S, R 10 W, were recently logged. Rotational failures that originated along the headwaters road formed debris slides that coalesced to form a massive torrent that apparently wiped out virtually every tree in that tributary's entire mainstem. This torrent apparently affected the right valley wall of Tioga Creek down a few hundred feet downstream of this tributary.

1979 John Anderson's Stream Survey

This survey, although 9 years after Boyce's, picked up where he had left off. Below is his notes that have been paraphrased.

Mi. 13.75-14.0 Menasha Corporation had recently clearcut much of the forest in Sec. 16 had resulted in log jams behind the old-growth root wads that formed the channel structure in this reach. A log jam around mi. 13.8 apparently "prevented coho and steelhead from moving upstream since 1975." Many of the logs were removed during the summer of 1979 although this was "conducted in such a manner that only new debris was taken out. All major structural members were left in place and any debris that was not in the main channel and appeared stable was left in place." The channel was composed of "a series of boulder cascades and wide gravel flats. The riparian canopy was "multistory with very old Douglas fir forming the overstory with bigleaf maple and red alder forming the next layer and young alder form an understory of recent vintage on some of the gravel flats created by log jams." Habitat condition was rated "good to excellent."

Mi. 14.5-15.1 This reach was "heavily modified" by Menasha's logging practices. Much of the timber had been yarded down hill to the stream with "a few token buffer trees" left. The channel was reportedly "heavily damaged by massive sluice outs from the areas that were logged on the slopes immediately above that channel" that were likely the source of the log jams recorded in the reach below. "Green algae on cobble and boulders dominated the channel with young alder" dominating the riparian. Around mi. 15, "natural boulder areas and small falls" were reported. Habitat condition was rated "fair to poor."

Mi. 15.1-15.45 This reach began at the north end of section 21. Riparian was old growth similar to that seen in mi. 13.75-14.5. The canyon narrows and steepens with riparian vegetation of red cedar and hemlock becoming more abundant. On gravel bars backed up by log jams, red alder and conifers, estimated at 4-6 years old (vintage '72-74), were growing. A 15-foot high waterfall was identified at mi. 15.2. Above the falls, two log jams were storing "substantial deposits of gravel where the gradient was "relatively flat." A "sluice out and log jam block the channel at mi. 15.45." A large patch of alder, about 10 years of age (vintage ca. 1970) was seen growing on the "sluice out and jam" area.

1986

The mainstem of Tioga Creek continued to incise. The lower creek was seen as a thin strip surrounded by a homogeneous riparian strip (*19-36A* -35-- *19-36A* -37). Two debris slides originated from a ridge-top road and recently logged area in the small Tioga tributary between Hatcher and Water Tank Creeks (*19-36A*-36). These slides were not new in '86. They showed up in the '76 photo (*9-30A*-25) which was taken prior to logging but subsequent to road construction. They were not seen however in the '64 photo (*1*-9), taken prior to road construction. This suggests that road construction helped initiate these two slides.

1992

The air photos show that the mainstem of Tioga Creek had continued to incise during the light precipitation years of the early '90's. Bars, bare and active in the 1960's and '70's, were covered with a canopy of red alders. Relatively minor peak discharges between 1987-'94 allowed the alders to gain a strong foothold on these bars.

Stage-discharge Relationship

Coos County has been operating a stream flow gaging station on Tioga Creek (#14-3225.00) since WY 1985. I compiled their stage-discharge records and plotted them over this 10-year period to evaluate vertical adjustments of the stream bed at the gaging station (Figure 13). The basis for this exercise was that if bed degradation is occurring, more sediment is being removed from the gage site than is being supplied from upstream, i.e. sediment deficit. This would be indicated as a shift of the rating curve to the left since for any given discharge, a lower stage is reached. On the other hand, if bed aggradation is occurring, more sediment is being supplied to the gage site than can be removed from it. This would be indicated by a shift to the right.

Figure 13 shows that a phase of degradation began during WY 1989 as indicated by the shift of the curve to the left (compare diamonds with solid circles). Degradation continued in the early 1990's which seemed to stabilize by 1992. Between 1985 and 1994, the bed of Tioga Creek at the gage degraded about 0.5 feet as indicated by the stage at 50 cfs.

Figure 12: Interpretation of photo, *8-29*-36 showing the extent of the slides, freshly scoured channels and debris torrent. Rotational slumps and scoured headwater channels shown in red. Unaffected, headwater channels shown in dotted blue lines.
(Note: The original for figure 12 was lost, and therefore unavailable for this edition of the document)

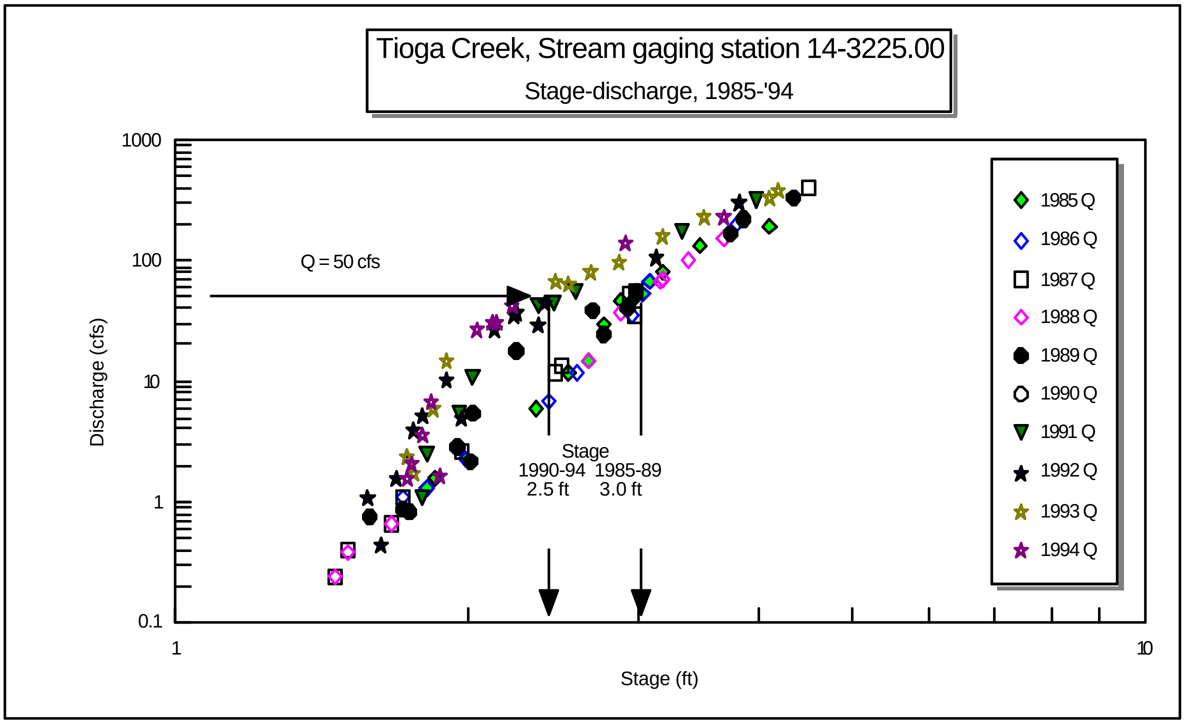

Figure 13: Plot of stage-discharge for 10 years, 1985-'94. A phase of degradation began during WY 1989 as indicated by an upward shift in the rating curve (compare diamonds with solid circles). Degradation continued in the early 1990's which seemed to stabilize by 1992. In the 10 years of record, the bed of Tioga Creek at the gage degraded about 0.5 feet as indicated by the stage at 50 cfs. **1996 FIELD OBSERVATIONS**

Lower Tioga Creek

Lower Tioga Creek has two recently-placed boulder weirs across it near the mouth. Gravels dominated the substrate at the mouth and 4-10 inch diameter red alders were growing on the floodplain. The floods of last winter, with peak discharges estimated at 10-15 year recurrence intervals, apparently mobilized many gravel bars and created a few new, minor log jams. In places, young (<10 year old) red alders growing on the stream banks were tilted but not scoured from their growing places.

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